Thermal Modeling of the Optical Telescope Assembly (OTA) for the Next Generation Space Telescope (NGST)

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OTA Thermal Analyses/Results Summary

Thermal Modeling Approach

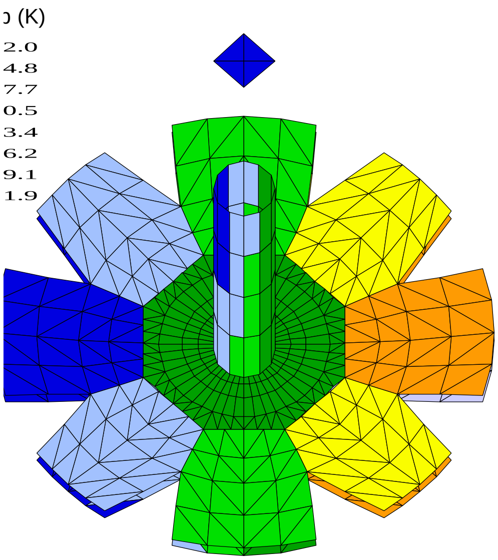
Utilized an in-house computer program to convert NASTRAN geometry data to TRASYS/SINDA format.

- NASTRAN triangle and quadrilaterial elements converted to TRASYS polygons.
- NASTRAN bar elements converted to cylindrical TRASYS struts with SINDA conductors based upon cross sectional area.
- NASTRAN FEM mesh converted to mathematically equivalent SINDA conductor network.
- Able to provide a 1-to-1 correspondence between NASTRAN and SINDA nodes.

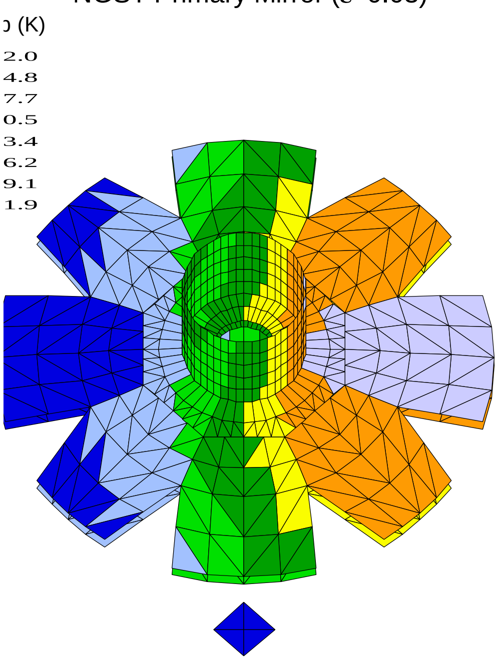
Steady State/Transient TRASYS/SINDA models

- Models include thermal conductance within the mirror, secondary mirror mast, and support structure
- Radiation exchange between all surfaces is included.
- Thermal path between mirror and support structure through actuators is included in the models.
- Transient models include the thermal mass of the mirror

Interdisciplinary Thermal/Stress Analysis

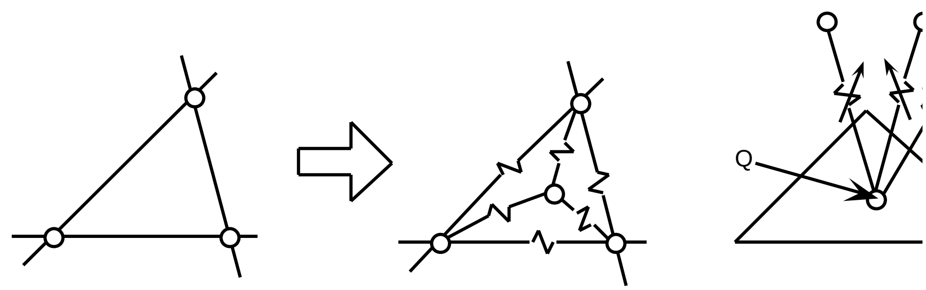


NGST Primary Mirror (ε=0.03)



NGST Reaction Structure (ε=0.73)

The thermal models used in the analysis of the NGST were cons
directly from NASTRAN models. An in-house computer program
developed to convert the NASTRAN geometrical data (triangular
quadrilateral finite elements) to TRASYS polygons. The NASTR
element mesh was converted to a mathematically equivalent SIN
thermal network. Internal structure, included as NASTRAN bar e
can was modeled radiatively with TRASYS and included in the S
thermal network solution as conductors derived from effective cro
sectional area and length. The resulting thermal models were ab
provide a one-to-one nodal correspondence with the NASTRAN r
while accounting for the thermal conductance within the optic and
radiation exchange between all surfaces.



NASTRAN Finite Element SINDA Thermal Network TRASYS Represe

The NASTRAN nodal points are represented in the thermal netw
SINDA arithmetic nodes. A diffusion node is added correspondin
centroid of the element, providing a convenient location to impos
loads and thermal mass and to attach radiation conductors.

TRASYS Modeling Assumptions

- Mirror segment actuators not treated radiatively
- NASTRAN RBEs (hinges, latches, drive motors) not treated radiatively
- Large view factors to space and radius of curvature of primary mirror justify diffuse radiation assumption using TRASYS
- View factors computed by Nusselt-Sphere method
- Infrared Emissivity numerical values

Emissivity Numerical Values

Primary Mirror Petals (both sides)	0.03
Primary Mirror Center Segment (both sides)	0.03
Support Structure Struts	0.03
Secondary Mirror Mast (both sides)	0.70 (Gr/Ep)
Secondary Mirror (facing Primary)	0.03
(facing deep space)	0.70
Sunshade	0.03

Assumptions on Emissivity Values

0.03 is typical for polished silver/gold coatings at room temperature

0.03 assumed for pure metallic materials (no surface defects). Assume beryllium has no impurities

0.70 assumed for Graphite/Epoxy (AXAF-I Solar Array GFRP Panels 0.70-0.80)

0.03 assumed for aluminized Kapton sunshade (from GSFC)

Assumptions in SINDA Modeling

No conductance in secondary mirror

No conductance path to sunshade (have done some analyses with conductive path to sunshade; will revisit this)

No conductance path for hinges & latches

Mirror facesheet and secondary mirror conical mast assumed isothermal across element thickness

Boundary conditions

Numerical values for thermal conductivity

SINDA Boundary Conditions

- Sunshade Temperatures (obtained from GSFC)
- Space (assumed 0 degrees Kelvin)
- No heat flux on OTA (only on sun shade)
- Zero actuator power dissipation assumed

Thermal Conductivity Numerical Values

Beryllium	100.0 W/mK
Graphite/Epoxy	1.0 W/mK
Titanium	4.22 W/mK

Beryllium value comes from Brush Wellman data: 100 W/mK on conservative end of 30-100 K range

Graphite/Epoxy number is uncertain: assumed very low for sake of conservatism

Titanium number comes from National Bureau of Standards data

Transient Analysis

- Time varying boundary conditions
- Initial BC: Sunshade normal to sun vector (sunshade temps from GSFC)
- Final BC: OTA at maximum slew angle away from sun (sunshade temps from GSFC)
- 1-hour slew followed by 27-hour settling time

Thermal Mass for Transient Analysis

Specific Heat for Beryllium is 34.1 J/kg-K from Brush Wellman data (value for 60 K).

Only the thermal mass of the primary mirror and reaction structure (in Be case) included. Temperatures of graphite epoxy elements computed using steady state assumption.

- Graphite epoxy volume fraction and layup not well defined
- Due to radiative coupling, the temperature of the secondary mirror mast not expected to influence settling time of the primary mirror

Future Work on Glass Mirror

Use NASTRAN model with coarse mesh & NASTRAN model with a single fine-meshed petal

Compare results

Size of fine mesh model could exceed capability of existing analysis code

Fine mesh could pose numerical problems for thermal analysis

Determine mesh density adequate for good thermal results

May require interpolation if structural and thermal mesh densities are different

Summary & Comments

Many details (hinges, latches, etc.) have been left out of the thermal model due to the preliminary nature of this study. Many of the omitted details were deemed to have negligible or higher order effects on the ultimate results. A typical Phase C/D effort would involve much more detail.

There is uncertainty in the numerical values of many material properties at the temperatures of interest. Usually a conservative approach has been used in assigning numerical values.